DOCUMENT RESUME

ED 415 665 EF 005 017

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TITLE	HVAC System Automatic Controls and Indoor Air Quality in Schools. Technical Bulletin.
INSTITUTION	Maryland State Dept. of Education, Baltimore.
SPONS AGENCY	Environmental Protection Agency, Washington, DC. Office of Radiation and Indoor Air.
PUB DATE	1996-06-00
NOTE	9p.
AVAILABLE FROM	Maryland State Dept. of Education, School Facilities Branch, 200 W. Baltimore St., Baltimore, MD 21201. (Free to Maryland public schools; $8 for others).
PUB TYPE	Guides - Non-Classroom (055) -- Reports - Research (143)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Air Conditioning; *Air Conditioning Equipment; Air Flow; *Climate Control; Elementary Secondary Education; Energy Conservation; Energy Management; *Heating; *School Buildings; Thermal Environment; Ventilation
IDENTIFIERS	*Control Systems (Mechanical); Facility Management; Heaters; *Indoor Air Quality

ABSTRACT

Fans, motors, coils, and other control components enable a heating, ventilating, and air-conditioning (HVAC) system to function smoothly. An explanation of these control components and how they make school HVAC systems work is provided. Different systems may be compared by counting the number of controlled devices that are required. Control systems are categorized according to their means of data processing, transmission, and power source: pneumatic, electric, electronics, direct digital, and self-powered. Likewise, the HVAC system is composed of various components: sensors, controllers, actuators (the system's power elements), and controlled devices, (e.g., dampers, valves, and speed regulators). All of these control elements work together to form a control loop. An overview of HVAC systems controls is offered, which focuses on unit ventilators, variable air volume systems, rooftop air conditioning, and supplemental systems. Monitoring the HVAC is also important, and methods such as multiple location supervision are explored. It is suggested that control system maintenance is another important component of any HVAC system, which entails the inventorying of tools and parts. Some control problems that may affect IAQ are provided. (Contains four figures, six references, and a glossary of terms.) (RJM)

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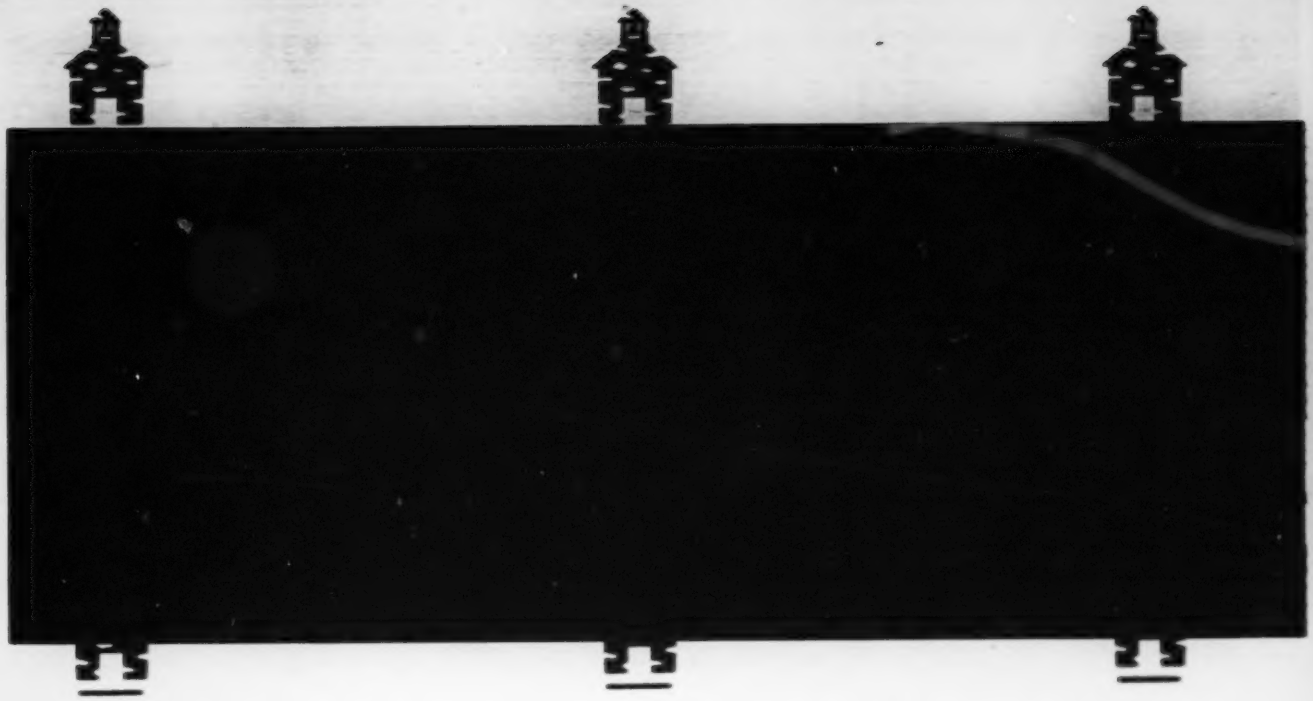

HVAC SYSTEM AUTOMATIC CONTROLS AND INDOOR AIR QUALITY IN SCHOOLS

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June 1996
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Introduction

Controls enable fans, motors, coils, and the many other items comprising an HVAC system to function together to produce satisfactory thermal conditions and air quality. The goal of this bulletin is to provide basic understanding of control components and how they are integrated and managed to make school HVAC systems work. Some specialized terms used in the bulletin, (noted with an asterisk), are explained in the Glossary at the end of the text. Focus of this bulletin is on the design and operation of the controls for HVAC systems serving general classrooms. The bulletin length precludes discussion of the specialized controls applicable to labs, cafeterias, boiler, chilled water plants and other subsystems.

Automatic controls are essentially communicators and information processors. A control familiar to all is the room thermostat. It senses space temperature and compares it to a set point predetermined by the occupant (or often in classrooms through internal adjustment by an authorized operator). In the typical classroom environment thermal loads change throughout the day and in time cause a deviation from the set point. The sensor communicates this to the thermostat mechanism which then directs power to an actuator that repositions a damper or valve thereby providing greater or less flow of the air or water delivering thermal energy to the room. Is the shift too much, too little or just right? Over time, the sensor will determine. Communication continues until the deviation is minimized. Thermal loads change, as lights are turned on and off, people come and go, and outdoor conditions fluctuate. The control is always at work.

This simple example is representative of an array of HVAC system controls, communicating with each other and reporting through monitoring equipment (thermometers, gauges, alarms) to facility managers. A well tuned, functioning control system is necessary for the HVAC system to perform adequately.

The inception of the HVAC control for a school should occur very early in the building design process. Performance requirements, monitoring provisions, complexity, even workability are determined in large measure during the concept design phase. The HVAC system selection is guided by the architectural design, environmental parameters, facilities management preferences, energy demands, code requirements, and cost budgets. Strengths and shortcomings of HVAC systems commonly employed in schools with respect to indoor air quality (IAQ) are covered in an earlier Maryland State Department of Education bulletin, *Selecting HVAC Systems for Schools (1995)*.

The impact of HVAC system selection upon comfort expectations is easily overlooked. The perception of IAQ is materially affected by space temperature and humidity. Controls are too often relied upon to function beyond their capability. For example, a room thermostat cannot sense humidity. If, as a function of the HVAC system, humid outdoor air at room temperature is introduced into the room, the thermostat is unknowing. The relative humidity can rise to excessive levels, frequently resulting in complaints about the air quality. Such conditions may also be conducive to producing biological growth (mold/mildew).

Systems may be compared by counting the number of controlled devices required...The multiplicity of controls and their relative inaccessibility can lead to neglect and malfunction.

As the design develops, control strategies become better defined. Provisions for monitoring within the building or remotely at an operations center are determined. Subsystem controls for air supply units, chillers, boilers are devised. Programmed automatic starting and stopping air systems, night set back for heating, and demand based ventilation are energy management functions that can be assigned to the control system.

Considerations often overlooked during design are complexity, maintainability and cost. Keeping the controls simple and accessible saves money. Selecting variable air volume (VAV) system controls, for example, to meet the goals of positive building pressure and controlled outdoor air for ventilation results in sophistication to the point of unworkability.

Facilities managers should be involved in the control design and selection process. Some districts have grown accustomed to certain HVAC and control system concepts. This can influence system selections without adequate regard for changing IAQ requirements and control technologies.

Honeywell concluded following a study of IAQ building problems that poor operation and maintenance of controls was a contributory cause in 90% of the cases and control design deficiencies in 75%. Greater emphasis must be placed upon automatic control design (and HVAC selection), operation, maintenance and management.

Each HVAC system type brings with it a characteristic arrangement of control components that together constitute a working system. Some elements, such as an outdoor air damper, often are assigned multiple tasks. This damper may be controlled to provide air for ventilation, space cooling when the outdoor temperature is suitable, building pressurization, and clearing an area of smoke in the event of a fire. Many of these components and their functions common to schools are described later.

HVAC system performance must be monitored. Traditional monitoring relies upon visual observation of gauges and thermometers at the equipment locations. However, remote monitoring at a central point within the school building or at a district operations center serving a number of schools can offer superior surveillance and result in reduced staff and speedier reaction time in the event of malfunction. Data gathering can also facilitate control and accounting of energy use.

Centralized communication from multiple locations becomes more difficult when control systems for the schools involved are of different age and manufacture. Compatibility considerations are discussed later in this bulletin. Therefore new and remodeled schools, while designed for monitoring and supervisory control based upon current technology, should also consider future developments. The district facilities manager has a key role in determining the monitoring strategy.

Control System Characteristics

Control components are categorized

according to their means of data processing, transmission and power source.

Pneumatic

Clean, oil and water free, compressed air, usually at 15psig pressure, is supplied to *controllers*" that regulate the pressure to actuators controlling the positions of valves, dampers or similar devices.

Electric

Electricity, rather than air, is the control power. The simplest electrical control is two position switching, such as on-off control of a fan motor.

Electronics

With electronic control, controller current output is usually modulated in proportion to the sensor signal.

Direct Digital

Direct digital control" (DDC) is a further development in electronics. In essence, a microprocessor controller converts a low voltage analog sensor signal to a numerically coded, digital instruction based upon a program of performance algorithms. Instruction is transmitted in digital form to a converter and then to an analog signal that positions the actuator. Several sources of input data may contribute to the signal processing. The microprocessor may be used to control more than one control circuit or loop.

Self Powered

Self powered controls are employed for some HVAC applications, but are usually cost saving adjuncts for special situations, such as isolated convector control.

HVAC systems utilize pneumatic, electric, and electronic control. In smaller schools pneumatic control systems are frequently selected due to cost. Larger schools usually have a hybrid system with digital controllers, small electric powered actuators and pneumatically powered actuators for larger dampers and valves.

Digital control technology is increasingly selected over pneumatic. Not always the least expensive, digital control has superior versatility, reliability and responsiveness. To be discussed later is the capability to transmit information and commands from supervisory control centers. The cost trend of digital systems is downward. Maintenance costs are reported to be less than half that for pneumatic, but this comparison depends largely on who does the maintenance. With inherent advantages, digital systems are likely to predominate in the future. The attributes of digital control can, however, lead to the excessive selection of control and monitoring features that can strain the project cost budget. An experienced control contractor, knowing that provisions for remote monitoring cost about $800 per installed point, can provide valuable cost control guidance during the design phase.

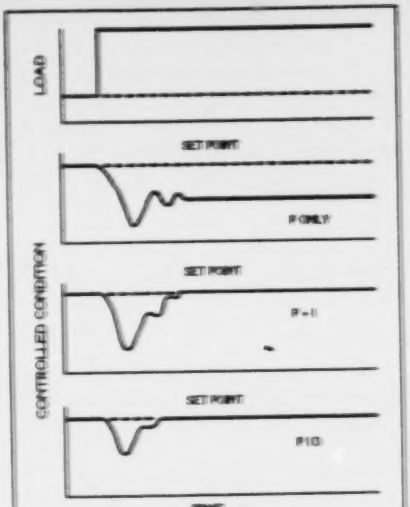

Figure 1 Controller performance P, PI, PID

Unlike pneumatic controls, many DDC components are not interchangeable with those of other manufacturers. While distribution system carriers may be similar, the "language" employed by different manufacturers is their own. This situation is changing and will be discussed further under Monitoring and Supervision.

System Components

Sensors

A sensor is a device that measures and detects a change in the temperature or other characteristics of air or water. These are the "point men" of the control system. Temperature sensors, in addition to those mounted on classroom walls also measure supply air, chilled water, hot water, and outdoor temperatures. Humidity sensors, now increasingly used in schools, respond to relative humidity. Differential pressure sensors are sometimes used to measure building pressure relative to outdoors, water system pressures, or the drop across filter banks. Air and water flows are measured in some systems. More recently, air quality sensors have been introduced for monitoring or ventilation control by measuring concentrations of contaminants. An important though specialized role for some HVAC sensors is safety, both for people and equipment. Smoke and fire detectors; high pressure cutouts in water, steam and air systems; and coil freeze protection thermostats are commonly incorporated into school control systems.

Controllers

The sensors report to controllers which determine the appropriate action needed to respond to a change in the measured characteristic of the medium. The response may be two position. It may be a *proportional*" (P) response corresponding to the deviation of the sensed medium from the set point of the controller. That set point may be selected by the occupant, as with a room thermostat, or predetermined by the HVAC system design. These latter set points are to be treated with respect. Any change must be recorded and justified. Improper control settings can result in IAQ problems. For example, too high a chilled water temperature control set point can lead to excessive space humidity.

When the sensed value deviates from the set point a proportional change in the signal adjusts the position of the actuator. Consequently the controlled value always deviates from the set point. This deviation is also called offset or proportional error. Proportional control can be improved by the addition of two features, *integral*" (I) action and *derivative*" (D) action. Integral action is used to eliminate the proportional controller deviation over time. A space temperature sensor linked to a PI controller can respond to load changes while maintaining the set point, thus avoiding the necessity of seasonal or more frequent thermostat adjustments. The supply air temperature can be controlled closely with minimal *hunting*" by application of a PI controller for chilled water flow to a large central station cooling coil. Derivative action is beneficial for processes requiring rapid time response, although it can be difficult to tune for stability. Many HVAC processes can be controlled adequately without it. Proportional control action generally provides stable control. Pneumatic controllers are also obtainable with "I" and "D". See Figure 1

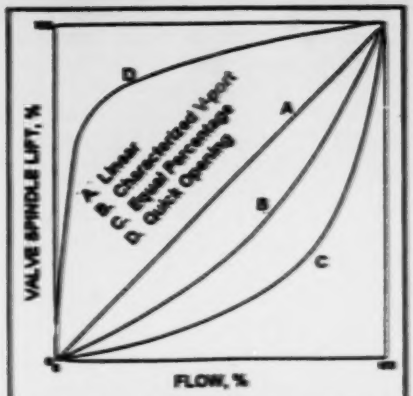

Figure 2 Economizer dampers selected for balanced operation

graphing these controller performance features.

Controllers may process information from more than one sensor or source. For example, a hot water temperature controller can be reset by the thermostat in the one zone among a total of ten that requires the highest water temperature for heating.

Actuators

These are the system's power elements. They reposition the controlled devices in response to the regulation of the controller. The signal itself can provide the energy or be used to direct a more powerful source. Small dampers and valves controlled by electrical or digital controllers are normally equipped with electric actuators. Air pressure usually in the range of 3 to 13 psig is preferred over electric power for large actuators. DDC control systems are equipped with transducers to convert the electric message to air pressure. To overcome *hysteresis** and insufficient power from a control signal, a power booster or positioner is applied to assure the controlled device assumes the position ordered by the control signal.

Controlled Devices

The list of controlled devices includes dampers that regulate air flow, valves that regulate water or steam flow, and speed regulators of fans and pumps. These are the performers of the controller system. Often the results of either proper control operation or malfunction is observable. If poor ventilation is suspected, the first place to check is the outdoor air damper. No cooling? Check the chilled water valve. No air flow? Check the fan operation. The engineering of dampers and valves entails selection based upon flow rate, available pressure to overcome flow resistance, maximum pressure differential when closed, tightness of shut off, pressure rating, and range of flow to be controlled. Should the pressure differential across the valve or damper change in the course of position changes, the flow performance characteristics is also affected. Selection for proportional control aims to provide capacity (not necessarily flow) approximately proportional to the controller signal through the entire control range. The task of the controller becomes quite difficult or in extreme cases impossible if improperly engineered. **Figure 2** shows characteristic curves for valves with different plug or port configurations. Similarly dampers, available with blades that operate in parallel or opposed to each other, have distinctive flow characteristics. Flow resistance(relating to the total system resistance) and the relationship between flow and process performance must also be part of engineering evaluation for both devices. **Figure 3** illustrates how properly selected blending dampers (as for an *economizer** control) can achieve a constant pressure differential and total system flow (excluding other system variables).

Dampers, valves, and their actuators require maintenance - both preventive and corrective. The order of difficulty of these tasks is affected by their number and accessibility. Systems may be compared by counting the number of controlled devices required and the inherent ease of their access. Dampers integrally supplied with VAV terminals and unit ventilators are selected for their duty within the limits of applicability of the equipment.

Some applications of either damper or valve control incur risk of system component damage in the event of serious malfunction or improper manipulation. For example, failure of a hot water valve supplying a coil heating a stream of freezing outdoor air can damage that coil and others downstream. Protective override controls, such as temperature limiting thermostats or pressure limit switches, must be incorporated into the control scheme where appropriate.

Fans and pumps can be controlled devices

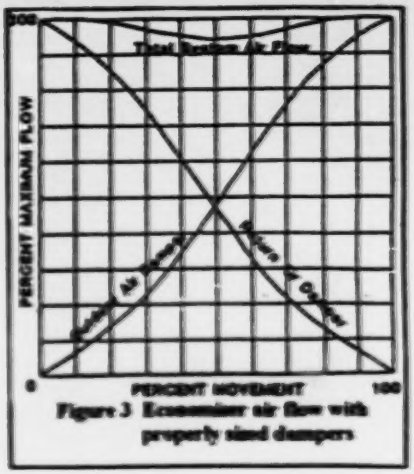

Figure 3 Economizer air flow with properly sized dampers

through on/off switching or to modulate capacity by motor speed control or integral inlet dampers. A VAV system supply duct pressure varies as space thermostats reposition terminal dampers for more or less supply air. To limit supply duct pressure, fan capacity is usually controlled. If a return air fan is employed, its capacity must be controlled to operate so that its air flow is synchronized with that of the supply fan.

Control Loops

The control elements previously described when combined to perform a complete control task comprise a control loop.

Room temperature is controlled by such a loop. A room thermostat, in which sensor and controller are combined, detects a drop in space temperature. The change (deviation from set point) initiates an action message or power change, such as increasing control air pressure, to a valve controlling hot water flow to a coil in the supply air duct. The valve opens, heat output increases and room temperature rises. If the deviation from set point is eliminated, no further action occurs. If it is not or if the deviation reverses, the cycle is repeated until equilibrium is restored. Because the results of its action are felt by the thermostat this loop is known as a *feedback* or *closed* loop.

In contrast, a thermostat sensing outdoor temperature, upon a temperature drop increases the temperature in the hot water circulating system. The heat output to the room also increases but there is no feed

back reporting whether the change was as needed. Thus the loop is an *open* loop, not suitable by itself to provide for occupant comfort or most other tasks where close control is desired.
The outdoor air ventilation supply may be controlled in an open loop by a switch.

For some systems, classroom humidity may be an indirect consequence of room temperature control. In warm humid climates this can prove a serious deficiency.

When indexed to occupied, a fan starts and the ventilation outdoor air damper opens. No further action occurs until the switch is repositioned to unoccupied.

Ventilation may be *demand* controlled, supplied as needed to dilute contaminants within the space served by the air supply system. The simplest demand control can be a time clock programmed to provide outdoor air ventilation prior to start of classes to flush out any residual contamination, then discontinuing it when classes are over for the day. A seven day clock can discontinue ventilation on week ends if not required. A remote instruction to this open loop control may discontinue outdoor air ventilation on a snow day. Where occupancy is concentrated (as in a classroom) and variable, but with predictable patterns, time control (open loop) of ventilation can be an effective energy saver.

Carbon dioxide concentration within a space is an indicator of occupant produced contaminants. CO_2 sensors can be employed to control dampers to reset the outdoor air ventilation rate to a baseline minimum (to account for other contaminant sources). This closed loop control responds both to the presence of people in the space as well as the ventilation rate. It is especially appropriate for spaces with unpredictable patterns of occupancy and where occupants are the principle contaminant source, as in an auditorium.

CO_2 sensors are now used for both control and monitoring to assure adequate ventilation. Somewhat more expensive and maintenance demanding than a thermostat, they can be used effectively if maintained. Other sensors of volatile organic compounds (VOCs) are available. However, considering the current state of sensor development and lack of knowledge regarding acceptable exposure to VOCs, such sensors can not be recommended for use in schools.

Economizer Control

Outdoor air is not solely for ventilation. It can also be introduced through air conditioning units to cool the building where seasonal variations make it practical (this includes most of the USA). Energy use for operation of refrigeration is reduced. Thus this loop is called the economizer cycle. Preferably outdoor air for this purpose is introduced into the mixing plenum section of the air conditioning unit through a damper separate from the ventilation damper. This damper is controlled by the mixed air temperature in concert with a damper through which warmer air from the building is returned. (This temperature is often sensed at the supply fan discharge and may also be used to control flow to cooling and heating coils in the air handling unit.) The blend maintains a preset supply air temperature. The cycle only functions when the air temperature or heat content outdoors is lower than indoors. An automatically controlled relief air damper is incorporated into the loop to avoid an excessive increase in building pressure when the supply air mix is mostly outdoor air. The relief air damper, though often linked with the outdoor air damper, is then insensitive to actual variations in building pressure. Several schemes are employed to maintain a slight positive building pressure. Most have shortcomings that must be reckoned with during design or, if not, during operation.

When the heat content of the outdoor air is greater than the return air, the control is shifted, manually or automatically, to supply only the minimum outdoor air needed for ventilation and positive building pressurization. An "occupied-unoccupied" mode can determine the ventilation rate, HVAC system operation, and night set back of space thermostat settings during heating. Mode control may be automatic or manual. Modes can direct the HVAC system to prepare for occupancy or provide for fire containment and smoke removal through fan and damper operation in the event of such an emergency.

HVAC Systems Controls - An Overview

HVAC control is accomplished through a combination of both open and closed loops. There is considerable interaction and interdependence.

Unit Ventilators

ASHRAE has classified alternative control arrangements for unit ventilation control. Classroom unit ventilator control combines controls for room temperature, economizer, outdoor air ventilation plus internal or external mode control with override. The unit enclosure may house a dozen or more control elements. Multiply that by the number of units and the total number of control elements to be maintained can become rather burdensome.

The multiplicity of controls and their relative inaccessibility can lead to neglect and malfunction. Unfortunately, such occurrences invite "Band-Aid" solutions rather than resolve a control problem. Outdoor air intakes are too often manually closed to "solve" poor temperature control performance during cold weather. For some classroom systems, such as those employing unit ventilators or factory built roof top units, space humidity is an indirect consequence of room temperature control. In warm humid climates this has proven to be a serious deficiency. During rainy weather, the room temperature sensor may call for minimal cooling. The moisture saturated ventilation air along with internal moisture sources (people are the main one) can increase the relative humidity beyond the limits for both comfort and acceptable indoor air quality.

For most VAV system configurations, digital controls offer superior performance for both the central air supply and terminals.

Variable Air Volume Systems

There are a variety of HVAC systems covered by the term variable air volume. In its most basic form as a cooling only system, the room thermal control loop varies the flow of constant temperature supply air to the room by modulating the VAV terminal damper in response to room temperature. The supply air is distributed to a group of classrooms as well as ancillary spaces from a central

conditioning unit. The cooling source is controlled to maintain the supply air temperature set point at the central unit. This may be PI control of chilled water to the cooling coil in warm weather and the economizer loop in cooler periods. Controls to provide warm air for use during a warm-up mode might also be present. Since supply air flow varies, a pressure sensor and controller are commonly employed to adjust supply fan capacity to maintain a narrow range of duct pressure. The return air fan, if employed, must be adjusted to coordinate with the supply fan output. Too much return air can lead to excessive relief, making building pressure negative. There are several ways to coordinate the operation of the two fans; none are without complexity. This loop requires careful design, installation and maintenance.

Even though supply air flow will vary, the need for outdoor ventilation air may not. Several control concepts are applied to maintain constant, or controlled, ventilation as many codes require. All must be carefully engineered for long term reliable operation.

VAV system controls thoughtfully provided and maintained can provide satisfactory service. **Figure 4** depicts an example of a VAV system control featuring a constant outdoor ventilation air supply by use of an injection fan and the lobby pressure for relief damper control.

High humidity is seldom a problem with VAV systems using proportional control of the supply air temperature. In contrast, excessive space relative humidity can occur with on/off cooling control found in many systems employing unitary equipment. Humid outdoor air and moisture reevaporated from the wet coil is supplied to conditioned areas during the off cycle.

Rooftop AC

On/off cooling is common among direct expansion factory built roof top air conditioners. Some units are designed to support VAV systems. Others are only suitable for constant air volume systems and may have limited ventilation capability. Controls are packaged with the units at the factory and customizing is seldom practical. The market is highly competitive. Features that might assure adequate ventilation and humidity control may not be included, especially on those

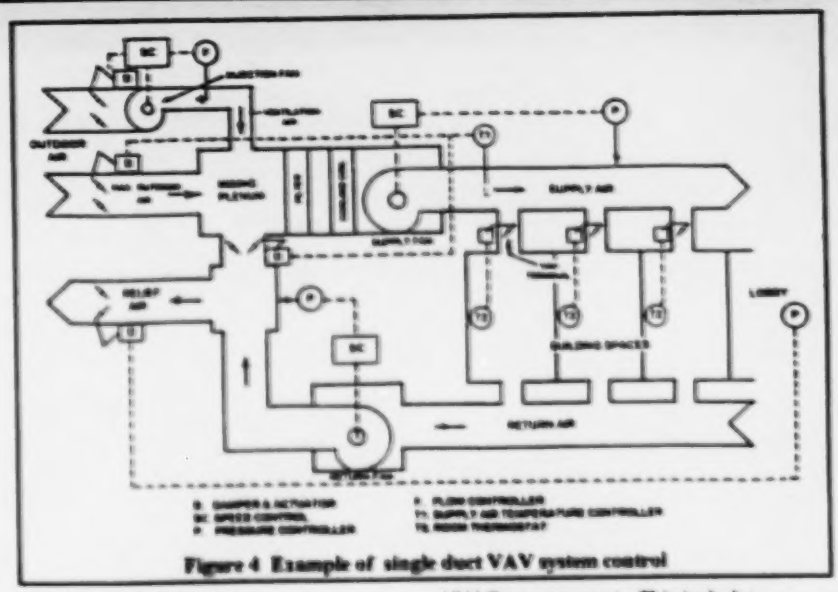

Figure 4 Example of single duct VAV system control

with the lowest price tag.

Supplemental Systems

To obtain improved humidity control, positive ventilation, and consequently improved IAQ, many new schools, especially in humid climates, are being designed with dedicated ventilation subsystems. Outdoor air for ventilation is filtered, dehumidified and controlled to a supply temperature near the acceptable room level. The air is distributed through ductwork to points of use. The temperature control for heating and cooling classrooms is assigned to complimentary terminal units such as fan coil or unitary water source heat pump units. Specialized packaged equipment with integrated controls is available for the outdoor air supply. Most incorporate energy conserving features.

Similarly integrated factory engineered controls are employed in the unitary heat pumps. Consequently the strategy of control maintenance for such equipment may lean more upon supplier support than district staff personnel. Such ventilation systems are added to upgrade existing unit ventilator and other systems that have been unable to provide adequate humidity and IAQ control.

HVAC Performance Monitoring and Supervision

Basic instrumentation at each school should be provided no matter how sophisticated the school district approach to HVAC management. This includes permanently mounted thermometers and pressure gauges or, alternately, wells and plugs for attachment of site located, regularly calibrated instruments. The latter concept requires fewer instruments and provides greater accuracy. A network connected, read only work station is an option to supplement an offsite control center.

Multiple Location Supervision

With digital systems, local area networks (LAN) can be linked to monitor key performance parameters and provide discrete system command authority for a number of schools from one location. Data is transmitted using a common ring or bus connecting the microprocessor controllers in each of the schools. Transmission from the school to the supervisory center can employ telephone modems, dedicated phone lines or dedicated network transmission cables. Messages to or from the microprocessors travel along the transmission paths as digitized data packets. Processors time share these transmission paths. The organization of the data and the traffic control to share the paths are accomplished through pre-established protocols. The protocol may be likened to a common language spoken by many voices but with one, or a limited number, speaking at a time. The voices - and listeners - may be microprocessors, computers, or work stations. In addition to serving HVAC systems, LANs are employed by security systems, fire control systems, school administration and

instruction. Gateways (translators) can be provided to connect the district LAN to other LANs using different protocols or wide area networks (WAN), such as Internet, Ethernet and LonWorks are popularly used technologies for data transmission and used by some control system suppliers for the network level transmission. A major impediment has been the proprietary language of each manufacturer. Systems of different manufacturers often can't talk to each other.

ASHRAE has developed a *communications protocol*" to overcome the language barrier for HVAC systems, called *BACnet*. BACnet has recently been adopted as ASHRAE Standard 135. For the near future, cost, marketing and technical considerations may inhibit its use. A client desirous of using central supervision in the manner described has been faced with the choices of standardizing on one manufacturer for systems control, network monitoring, or both.

Common practice has been to overlay a monitoring network of Manufacturer A on top of Manufacturer B's control system, but only with a degree of redundancy. Manufacturer A must provide sensors and processors already provided by Manufacturer B. This, of course, is disadvantageous to the school district customer.

Another choice is to wait for BACnet, which utilizes Ethernet (or some other standard technology) for transmission path management to break down the barriers. Simply put, BACnet is intended to provide a total standard for data transfer. However, BACnet may have its greatest benefit at the *network level*" transmitting information and action commands between a district management center and the schools it supports.

Some manufacturers favor simpler protocols, such as in LonWorks, especially for *zone level*" operations, e.g. for chillers and boilers. Actually, many digital processor and communication technologies are currently proprietary. A consortium of control manufacturers is working toward a simplified standard protocol to achieve interoperability of their control components for use chiefly at the zone level which would complement BACnet operating at the network level. Communication paths between controllers, actuators and monitoring stations within a school may involve two or three local networks, each dedicated to different tasks. Gateways can provide bridges to permit data flow to and from these zone level LANs to the district's LAN.

Connecting various existing school networks to link onto the district LAN and translating to its protocol is likely to be difficult and costly. Accordingly, provision for integration into a district network is perhaps better viewed as a long range strategy. Future integration then becomes a design consideration for every new or upgraded control system.

Control System Maintenance

Districts often have a cadre of control specialists to routinely service and trouble shoot all systems. This entails some inventorying of tools and components. Tools for IAQ may include temperature and humidity indicators (digital readouts are easily read and save time) and loggers, air flow measuring devices, and CO_2 detectors. Portable computer terminals, read only or with password accessed command authority, can be an effective tool.

Specialists need to be trained. Experience training can be the most effective but sometimes the most expensive. Courses are frequently offered in major cities by control companies. Key personnel that attend may then train others "in house". School district resources being limited, support by control contractors to supplement school district personnel is at times appropriate.

Some districts choose to subcontract all control maintenance, even extending such contracts to include all HVAC maintenance. The appropriate choice depends upon specifics of each situation. Either course demands oversight to assure effectiveness. Control neglect is a continuing concern and it will ultimately result in environmental dissatisfaction and impairment of the educational mission.

Preventive maintenance schedules, instructions and event records can be stored, retrieved and task assignments made through available computer software.

Glossary

Controller: A device that senses changes in the controlled variable (or receives input from a sensor) and derives the proper corrective output.
Thermostat: Sensor/controller responsive to changes in temperature.
Night setback (or setup): Reset of a thermostat setting usually coupled with a return event to a desired daytime setting.
Sensitivity: The increment of sensed change to initiate a controller response action.
Proportional control: Control action repositioning the actuator in proportion to the deviation or offset from the controller set point.
Proportional band: The span of values of the sensed variable necessary to reposition the actuator through its full range of movement.
Integral: Automatic shift to minimize the deviation from set point of a proportional controller.
Derivative: A response to rate of change of deviation from set point allowing faster PI control action.
Hunting: Undesirable oscillation of a controlled device causing a continuous swing in both directions from the set point.

Control Problems Affecting IAQ

Inadequate ventilation: outdoor air dampers closed to save energy or to avoid nuisance shutdowns from freeze stat protection, frozen coils, drafts, excessive humidity; room supply air imbalance; outdated controls.

Excessive room humidity: unconditioned outdoor air being introduced; high chilled water temperature; cooling coil bypass damper open or leaky; outdoor air damper open in unoccupied mode; building under negative pressure due to improper supply and return fan synchronization.

Space temperature too hot or too cold: room thermostat out of calibration; faulty terminal controls; improperly controlled supply air temperature; thermostats damaged by tampering or vandalism; seasonal mode inflexibility; inadequate room air supply.

Widespread incidence of sick building syndrome: no simple diagnosis. May originate with any of the three conditions above.

Hysteresis: Difference between the response of a system to increasing and decreasing signals.
Turndown: Ratio between maximum usable flow and minimum controllable flow through a valve or damper.
Digital control: Control loop in which a microprocessor using digital language and programmed logic determines the output to the controlled device.
Communications medium: Physical pathway over which data is communicated. Typical for LANs: twisted wire pairs, coaxial cable, and fiber optics.
Communications protocol: Encoding and decoding digital data for transmissibility between control system components over suitable media. Protocol may be proprietary, open (publicly available documentation) or standard.
Air Economizer: Controlled introduction of outdoor air in excess of the minimum for ventilation to perform cooling whenever its heat content is lower than that of recirculated air.
Network level: Communications tier most suited for data acquisition, supervisory control and multiple system integration.
Zone level: Communications tier utilized for intercommunication within HVAC component loops, such as unit ventilator, VAV terminal, air handling unit controls.

Illustration Credit

Figure 1 &2 Applications Manual, Automatic Controls, Chartered Institute of Building Services, London, Eng.
Figure 3 ASHRAE Journal, June 1987
Figure 4 Wheeler Engineering

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This Bulletin was developed and published, in part, with funds from the U.S. Environmental Protection Agency, Indoor Environments Division.

Participation on The Bulletin Review Committee does not imply agreement with the entire content of this bulletin.

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